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Enclosed for filing is the patent application of Inventor(s):
VLADIMIR R. PISARSKY

For: SECURITY MONITOR OF SYSTEM RUNS SOFTWARE SIMULATOR IN PARALLEL

ENCLOSED ARE:

- [X] Appointment of Associates;
[] Information Disclosure Statement, Form PTO-1449 and copies of documents listed therein;
[] Preliminary Amendment;
[X] Specification (9 Pages of Specification, Claims, & Abstract);
[X] Declaration and Power of Attorney:
(1 Page of a [X]fully executed []unsigned Declaration);
[X] Drawing (1 sheet of [X]informal []formal sheets);
[] Certified copy of application Serial No. ;
[X] Authorization Pursuant to 37 CFR §1.136(a)(3);
[] Other: ;
[X] Assignment to PHILIPS ELECTRONICS NORTH AMERICA CORPORATION.

FEE COMPUTATION

CLAIMS AS FILED				
FOR	NUMBER FILED	NUMBER EXTRA	RATE	BASIC FEE - \$690.00
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Independent Claims	3 - 3 =	0	X \$78 =	0.00
Multiple Dependent Claims, if any			\$260 =	0.00
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SECURITY MONITOR OF SYSTEM RUNS SOFTWARE SIMULATOR IN PARALLEL

FIELD OF THE INVENTION

The invention relates to security measures against viruses and hackers attempting to attack an electronic system with distributed functionalities. The invention relates in particular, but not exclusively, to a home network environment.

BACKGROUND ART

Security of computer systems and networks is being challenged by hackers and by computer viruses.

The term "hacking" is colloquially being used to refer to attempting to gain unauthorized access to another party's computer system or network. Although not all hackers have malicious purposes, such security breaches can have serious consequences if it leads to stealing or corrupting electronic information or to crashing the system.

A virus is a piece of code that gets loaded onto the computer system and executed without the user knowing about it. A typical example of a virus is a program that replicates itself. A possible hazard of such a virus is that it quickly occupies all available memory, thus bringing the system to a halt. If the virus is capable of transmitting itself across networks and bypasses security systems it can spread the disaster.

SUMMARY OF THE INVENTION

With the advent of home networks and home gateways, security against hackers and viruses is also becoming a concern to consumers in a domestic environment. A home network couples apparatus in a control network and/or communication network. These networks often also provide Internet access and cover mobile users via wireless modems, thus exposing the home to unauthorized electronic access from outside.

The invention provides, among other things, a solution to this security problem. More particularly, the invention considers a distributed information processing system that comprises a cluster of interacting devices or appliances forming, e.g., a home network. The devices or appliances have finite state machines (FSM's) onboard for the purpose of monitoring the cluster's

integrity. The system has a control server running a simulator of the cluster's FSM's. Each respective device's FSM calculates per time step a respective numerical value that depends on the values of the other devices' FSM's in the previous step, on the respective device's internal state(e.g., based on the device's memory's and I/O message buffers' content), and on a history of the previous values. This mathematical relationship is chosen such that it causes the collection of FSM's to behave as if they formed a dynamic non-periodic stochastic process. The simulator does the same on the server. The results of the simulator and the devices' FSM's should be identical. Upon a mismatch, an alert is generated. The security of the system resides in the facts that in order to be able to hack the system, the hacker needs to have a snapshot of the values of all FSM's at a certain step, to collect the values of the steps taken into account in the history, and to get into the internal states of each device. All these manipulations need to be performed in one time step, which makes it a complex computational task and practically impossible due to the distributed character of the system. An additional measure is to allocate computation time of the CPU per device for the full 100% to the calculation of the numerical value by maximizing the number of previous states taken into account. If there is a need for compute time, the number of previous states is reduced. A virus needs a processing environment to be active. By means of fully occupying the CPU, there will be no computational environment available to the virus to settle.

The invention can well be used in a home control network, wherein appliances have simple processors to generate the numerical value of the FSM's.

BRIEF DESCRIPTION OF THE DRAWING

The invention is explained below in further detail, by way of example and with reference to the accompanying drawing wherein:

Fig.1 is a block diagram with a monitoring system in the invention; and

Fig.2 is a mathematical expression representing an FSM.

DETAILED EMBODIMENTS

In many different situations, there is a need to monitor the operation of a technical system to ensure integrity, security and correctness of the actions of the system. The type of system

considered below is one that is implemented as a distributed network of devices. The devices have CPU-based controllers and are capable of exchanging information. The operation of the system is considered as the operation of a network of FSM's or extended finite state machines (EFSM's). An EFSM is an FSM with local constraints or local data variables. Examples of systems that can be modeled after FSM's are industrial automation and control systems, home networks, medical life support equipment, etc.

One of the problems that the invention seeks to solve is how to build a control and security system that issues an alarm in case of a failure, that may be caused by natural or malicious influences. Another problem addressed by the invention is how to block unsanctioned re-programming hacking and software virus infestation.

The inventor proposes several security layers that can be applied individually or combined in order to increase protection, robustness and security of the system. In the detailed discussion below the following definitions are being used:

- SYSTEM: the conglomeration of the devices under consideration that needs to be monitored and defended;
- DEVICE: a component of the SYSTEM that includes a CPU-based controller;
- DEVICE STATE INFORMATION (DSI): control code calculated by some rules in the DEVICE's memory, possibly including the DEVICE's I/O message buffers;
- CONTROL SERVER: computer outside the SYSTEM that is monitoring operations of the SYSTEM and that is capable of issuing the alarm;
- SIMULATOR: simulation software simulating the SYSTEM as a distributed network of EFSM's.

Fig.1 is a block diagram of a system 100 in the invention. System 100 comprises a SYSTEM 102, e.g., a home network. SYSTEM 102 includes DEVICES 104, 106, ..., 108. Each of DEVICES 104-108 has a respective FSM 110, 112, ..., 114. System 100 further comprises a CONTROL SERVER 116 that runs a SIMULATOR 118 simulating the behavior of SYSTEM 102 in software. The results of SIMULATOR 118 are compared with the states of DEVICES 104-108 in an evaluator 120 to issue an alert upon detection of a discrepancy.

In a first one of the security layers SIMULATOR 118 is run on CONTROL SERVER 116. For each discrete time step the CPU of each of DEVICES 104-108 calculates a respective

DSI associated with the relevant DEVICE. This DSI is compared with a corresponding DSI code that is calculated for that DEVICE by SIMULATOR 118. A mismatch between these values is an indication of operational failure or of illegitimate reprogramming of SYSTEM 102.

Fig.2 is a mathematical expression defining an FSM. A value $X_k(t)$ is calculated for each DEVICE (k) for each time step "t" according to this expression, wherein:

- "t" is the current moment in time;
- "k" is the index or label for DEVICE (k), running from 1 to M , assuming the number of DEVICES equals M (M equals 3 in the illustrated example);
- " S_k " is the DSI of DEVICE (k); and
- " $F_k(., ., .)$ " is the "k"-th component of a mathematical vector function chosen such that the set of M equations describes a stochastic non-periodical dynamic process.

Accordingly, $X_k(t)$ for a fixed "k" depends on the values X of all DEVICES 104-108 taken at the previous time step, on the DSI of DEVICE (k), and on the history of the value X for DEVICE (k). The length of the history taken into account is determined by the number N. SIMULATOR 118 calculates these values $X_k(t)$ for all "k" in each time step using the same mathematical correspondence. Each time step the values $X_k(t)$ as calculated by DEVICES 104-108 are compared with the values $X_k(t)$ as calculated by SIMULATOR 118. A discrepancy is an indication that the integrity of SYSTEM 102 has been violated.

In order to reprogram any of DEVICES 104-108 or in order to issue some extra command directly and with effect on SYSTEM 102, a virus or a hacker has to penetrate all DEVICES 104-108 of SYSTEM 102 and has to collect the required history $X_k(t-1)$, $X_k(t-2)$, ..., $X_k(t-N)$ for all DEVICES 104-108. Due to the stochastic nature of the evolution of the model given by the set of equations of Fig.2, all these manipulations are to be performed during one time step. This makes undetected hacking of interfering with SYSTEM 102 technically and computationally a very complex task

A computer virus needs a CPU resource from at least one of DEVICE 104-108 in order to perform its tasks, including the activities of hiding and mimicking. The inventor therefore proposes to reduce or eliminate CPU idling in order to prevent creating a suitable environment for the virus. This can be done, for example, as follows.

Initially, i.e., at $t=0$, SYSTEM 102 is loaded with equations as discussed under Fig.2, so

that it takes all extra CPU resources of each DEVICE beyond those needed for the primary tasks of the DEVICE. This can be one, for example, by increasing the computational complexity of the dynamic process by means of increasing the quantity N that determines the length of the history or recursion taken into account. If the DEVICE needs additional CPU power during operational use of SYSTEM 102, then the number N is decreased dynamically under control of an appropriate scheduling algorithm. These manipulations are performed on SYSTEM 102 as well as on CONTROL SERVER 116 so as to conserve the match between the calculated and operational values of the stochastic process. SIMULATOR 118 is therefore notified of these updates 122 to maintain this consistency.

CONTROL SERVER 116 can be a trusted well protected apparatus in the same geographic environment, e.g., the home, as SYSTEM 102. Alternatively, CONTROL SERVER 116 is a remote server of a trusted party.

In summary, the inventor proposes to simulate in software a primary system of multiple devices and to evaluate the behavior of the actual devices with respect to the simulations in order to detect legitimacy of the system's operations. The devices have FSM's. A stochastic discrete set of equations is used to cross-bind states and inter-device messages so as to make it impossible to predict and pre-calculate the primary system's control code values. As an anti-virus measure a computational environment is created that minimizes availability of computational resources to a virus. The latter can be implemented by usage of dynamically variable depth of recursion in the set of discrete equations as a mechanism to absorb idle computational resources.

WHAT IS CLAIMED IS:

1. A monitoring system comprising:

- a primary system with multiple devices; and
- a simulator for simulating behavior of the primary system;

wherein:

- the monitoring system evaluates a result supplied by the primary system with respect to an outcome calculated by the simulator in order to monitor the primary system.

2. The system of claim 1, wherein:

- each respective one of the devices comprises a respective finite state machine;
- the respective state machine calculates per time step a value of a quantity according to a respective mathematical function;
- the respective mathematical function has as arguments:
 - the value of the quantity calculated at a preceding time step by at least another one of the state machines;
 - a respective history of values assumed by the quantity calculated by the respective state machine;
 - a respective control code determined by content present in a memory of the respective device at the time step;
- the respective mathematical function is such that the quantity assumes a stochastic behavior.

3. The system of claim 1, wherein:

- each respective device has a respective computational resource;
- each respective one of the devices performs a respective primary task using the respective resource; and
- depending on the respective primary task, each respective device performs a respective secondary task for reducing availability of the respective computational resource.

4. The system of claim 2, wherein

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- each respective device has a respective computational resource;
- each respective one of the devices performs a respective primary task using the respective resource;
- depending on usage of the resource for the respective primary task, each respective device performs a respective secondary task for reducing availability of the respective computational resource; and
- the respective secondary task comprises calculating the quantity using adapting a length of the respective history.

5. A method of enabling to protect a primary system that has multiple devices, the method comprising:

- simulating a behavior of the primary system; and
- evaluating a result supplied by the primary system with respect to an outcome calculated by the simulator.

6. The method of claim 5, wherein:

- each respective one of the devices comprises a respective finite state machine;
- the respective state machine calculates per time step a value of a quantity according to a respective mathematical function;
- the respective mathematical function has as arguments:
 - the value of the quantity calculated at a preceding time step by at least another one of the state machines;
 - a respective history of values assumed by the quantity calculated by the respective state machine; and
 - a respective control code determined by content present in a memory of the respective device at the time step; and
- the respective mathematical function is such that the quantity assumes a stochastic behavior.

7. The method of claim 5, wherein:

- each respective device has a respective computational resource;

- each respective one of the devices performs a respective primary task using the respective resource; and
- the method comprises enabling each respective device to perform a respective secondary task, depending on the respective primary task, for reducing availability of the respective computational resource.

8. The method of claim 6, wherein

- each respective device has a respective computational resource;
- each respective one of the devices performs a respective primary task using the respective resource;
- the method comprises enabling each respective device to perform a respective secondary task, depending on the respective primary task, for reducing availability of the respective computational resource; and
- the respective secondary task comprises calculating the quantity using adapting a length of the respective history.

9. A device having a computational resource for performing a primary task, and comprising an FSM, independent of performing the primary task, for enabling to monitor an integrity of the resource.

A monitoring system monitors a system that has multiple devices that perform respective primary tasks. For the purpose of the monitoring, each device has a finite state machine (FSM) with stochastic non-periodic behavior. The monitoring system simulates in software the behavior of the FSM's. A discrepancy between the states assumed by the FSM's after each time step and the states assumed in the simulation in each time step indicates a failure or a breach of the network's integrity. Hacking such as primary system is practically impossible without being detected. Each device comprises computational resources. In order to reduce the computational environment available to a virus, the idle time of the resources is absorbed by dynamically increasing the complexity of the FSM's.

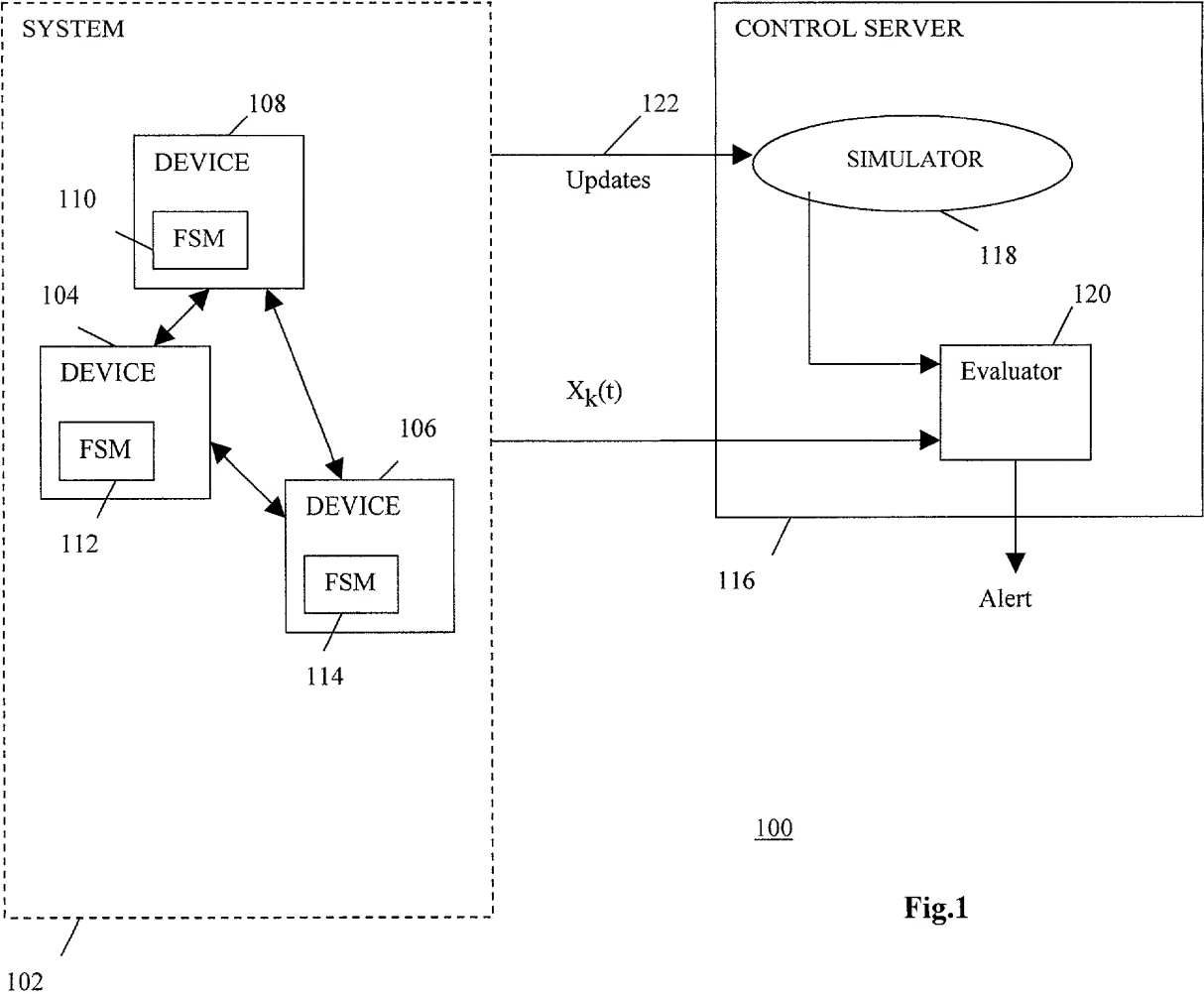


Fig.1

$$X_k(t) = F_k(X_1(t-1), X_2(t-1), \dots, X_M(t-1), S_k, X_k(t-2), X_k(t-3), X_k(t-4), \dots, X_k(t-N))$$

Fig.2

DECLARATION and POWER OF ATTORNEY

Attorney's Docket No.

US 000 262

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **SECURITY MONITOR OF SYSTEM RUNS SOFTWARE SIMULATOR IN PARALLEL** the specification of which (check one)
X is attached hereto.

_____ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by the amendment(s) referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulation, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

COUNTRY	APPLICATION NUMBER	DATE OF FILING (DAY, MONTH, YEAR)	PRIORITY CLAIMED UNDER 35 U.S.C. 119

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application (s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

PRIOR UNITED STATES APPLICATION(S)

APPLICATION SERIAL NUMBER	FILING DATE	STATUS (PATENTED, PENDING, ABANDONED)


I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

Michael E. Marion, Reg. No. 32,266

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Dated: <u>Sept 22, 2000</u>		INVENTOR'S SIGNATURE: 		
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
In re Application of Atty. Docket

VLADIMIR PISARSKY

US000262

Filed: CONCURRENTLY

SECURITY MONITOR OF SYSTEM RUNS SOFTWARE SIMULATOR IN PARALLEL

Commissioner for Patents, Washington, D.C. 20231

APPOINTMENT OF ASSOCIATES

Sir:

The undersigned Attorney of Record hereby revokes all prior appointments (if any) of Associate Attorney(s) or Agent(s) in the above-captioned case and appoints:

EDWARD BLOCKER

(Registration No. 30,245) and

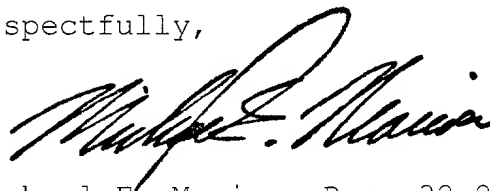
NORMAN N. SPAIN

(Registration No. 17,846)

c/o U.S. PHILIPS CORPORATION, Intellectual Property Department, 580 White Plains Road, Tarrytown, New York 10591, his Associate Attorney(s)/Agent(s) with all the usual powers to prosecute the above-identified application and any division or continuation thereof, to make alterations and amendments therein, and to transact all business in the Patent and Trademark Office connected therewith.

ALL CORRESPONDENCE CONCERNING THIS APPLICATION AND THE LETTERS PATENT WHEN GRANTED SHOULD BE ADDRESSED TO THE UNDERSIGNED ATTORNEY OF RECORD.

Respectfully,



Michael E. Marion, Reg. 32,266
Attorney of Record

Dated at Tarrytown, New York
this September 26, 2000.